THE AFRICAN JOURNAL OF Tropical Hydrobiology and Fisheries

(Afr. J. Trop. Hydrobiol. Fish.)

SPECIAL ISSUE II

East African Literature Bureau

NAIROBI DAR ES SALAAM KAMPALA

SPONSORS

Hydrobiologists from East, Central and West Africa·with substantial support from other Mrican countries, Fishery Scientists in the United States, Canada, U.K., Europe and the Soviet Union.

PROGRAMME

The- African Journal of Tropical Hydrobiology and Fisheries will only accept original and well supported ideas on techniques, methodology and research findings from scientists, fishery officers,. fishery economists and sociologists.
The Journal will therefore strengthen the African lesearch scientist by making research material available and a)so increasing the awareness and utility of aquatic resources.
Its quality will conform to International standards, and will be published in English and French.

MANUSCRIPT ADDRESS

Manuscripts should be addressed to E.A. F. F.R.O., East African Freshwater Fisheries, Research Organisation, East African Community, Box 343, Jinja, Uganda.

REPRINTS

Authors will receive 60 reprints free of charge. Extra reprints may he procured on cost.

PUBLISHER

East African Literatllle Bureau, P.O. Box 30022, Nairobi, Kenya.

ISSUES

The Journal consists of one volumc a year, consisting of two issues with approximatcly cighty pages each.

SUBSCRIPTION

Annual subscription within East Africa Sh. 35. Outside East Aflica, East African Sh. 70, US $ 10.00

THE RELEVANCE OF LIMNOLOGICAL INFORMATION IN THE DEVELOPMENT AND MANAGEMENT OF INLAND FISHERIES

G E. B. KITAKA
Limnologist
East African Freshwater Fisheries Research Organization
P.O. Box 343, *Jinja, Uganda*

The purpose of this paper is not to justify the existence of limnologists in fishery science, but to illustrate the now well accepted view that limnology holds the key to the understanding of fish production, and that an understanding of environmental relationships and the modification rates at all trophic levels must be the basis of enlightened management.

In its broadest sense, limnology is the study of all events characteristically occurring in freshwater bodies. It includes the study of the whole sequence of geological, chemical, physical, and biological events that operate together in a lake or stream basin, and are dependent on one another (HUTCHINSON 1957).

The geological history of the rocks of a lake basin and its drainage system, and therefore their chemical composition, is what in the first instance determines the chemistry of its waters (PEARSALL 1921; RYDER 1965). This in turn determines its type of plant and animal life. Collections of plankton throughout the year from any lake show a "seasonal" periodicity which is now believed to be associated with variations in the relative amounts of those nutrient salts in the water most important to the growth of particular phytoplankters (LUND 1958, 1965; VAN LANDINGHAM 1964; HUTCHINSON 1967; KILHAM 1971), though there are times when essential food materials are present in quantity and growth fails to occur. But the periodic fluctuations in the amounts of essential nutrients are themselves controlled by biological, physical, and chemical factors, such as their removal by the growth of plants, their eventual release by the living and dead organisms, and their chemical precipitation and dissolution in the water and sediments. The mechanisms of all these processes are greatly influenced by the physical state of the water column such as its temperature, transparency, currents, and stratification regimes. These few examples illustrate the interdependence of the major disciplines of science, namely geology, chemistry, physics, and biology, in limnology. We can, therefore, redefine limnology as the study of biological production-including that of fish-in fresh water as influenced by the environment.

Fish management has been defined as the art and science of producing annual crops of wild fish for recreational and commercial uses (BENNETT 1962). However, it now seems that fish management does not only concern itself with producing sustained annual crops of wild fish, but also with producing the highest sustainable annual crop of wild fish of the best quality in the most economic way. It is, therefore, important to understand as clearly as possible the factors which determine the numbers, biomass and distribution of fish populations so as to be able to manipulate their dynamics to improve the quality and value of the yield of important species. Information on rates of recruitment, growth, and mortality is essential, at least for the purpose of calculating production. But in order for such information to be used for predictive purposes in formulation of management decisions, the dominant density independent and density dependent variables must be recognized. These include the abiotic environment and the communities of other interacting organisms which serve as food, competitors, or as agents of nutrient fluctuations. Most of these variables are, to a large extent, limnological in character.

Unfortunately, it is very rare that the two types of information, limnological and fishery, are obtained simultaneously. Nevertheless, limnological information can still have predictive value in formulation of management policies, especially if collected over a long period of time to provide definite seasonal patterns of those variables which fluctuate with time. The parameters normally measured by limnologists include:

(1) Physical factors such as morphometry: of the water basin, water level fluctuations, air and water temperatures, wind speeds and direction, incident light intensity and light penetration, currents, etc.

(2) Chemical factors such as dissolved oxygen, carbon dioxide, hydrogen sulphide, and even nitrogen and methane;- pH, total dissolved solids, organic and inorganic nutrients, e.g., PO_4P, $NO_3.N$, $NO_2.N$, NH_4N, SiO_2, SO_4, Ca^{++}, Mg^{++}, Fe, Na^+, K^+, etc.

(3) Biological factors relating to the production and distribution of phytoplankton, zooplankton, benthos, periphyton, macrophytes, bacteria, etc.

Such parameters, singly or in combination, could be, and have in fact been, used to identify suitable and unsuitable habitats for fish, and therefore to predict the vertical and horizontal distribution of different fish populations at different times of the year, the practicability of introducing new species, the potential fish production of natural and artificial lakes, and even to increase the fish production of these lakes.

It is now common knowledge that the horizontal distribution of bottom-feeding fishes can be related to the distribution of acquatic benthic invertebrates (RAWSON 1947, 1955). In Tuttle Creek Reservoir, Kansas, for example, KLASSEN and MARZOLF (1971) have shown relationships between the distributions of the dominant benthic organisms and of some size classes of the bottom-feeding fishes studied. River carpsuckers *(Carpiodes carpio)* of all sizes tended to be caught in the muddy inshore areas where their dominant food was periphytic plant material supplemented with microcrustaceas, but their distribution did not appear to be controlled by that of the aquatic insects. However, it was found that although the large size channel catfish *(Ictalurus punctatus)* and freshwater drum *(Aplodinotus grunniens)* fed on a variety of food items besides aquatic insects (including fish), the young stages of both species fed exclusively on aquatic insects, and their concentration was predictable according to the distribution of aquatic insects, especially mayfly nymphs. The distribution of benthic organisms is also influenced by environmental factors. NORTON (1968) (quoted by SUMMERFELT 1971) has found that variation in abundance in the horizontal distribution of certain taxa of benthic macro-invertebrates in Lake Carl Blackwell, Oklahoma, could be partly related to variation in environmental parameters: in June, 1967, NORTON found that depth of water (negative correlation), organic content of sediments (positive correlation), and hydrogen-ion concentration (negative correlation) accounted for 30% of the variation in the total biomass of benthic macro-invertebrates. Working on the same lake, SUMMERFELT (1971) found that there was generally a positive correlation between abundance of a fish species and its forage, although a few species such as carp *(Cyprinus carpio)* and channel catfish showed no relationship between their catch rates and the independent variables examined, including water depth, sediment characteristics, and abundance of benthic macro-invertebrates. Variability in catch rates of white crappie *(Pomoxis annularis),* which fed on mayflies and gizzard shad *(Dorosoma cepedianum),* and freshwater drum which fed exclusively on oligochaetes, were positively correlated with the biomasses of these food organisms. The piscivorous flathead catfish was most abundant where freshwater drum and gizzard shad were abundant; the latter being its major forage items. Water depth indirectly influenced catch rates of benthic invertebrate feeders through *its* influence on sediment characteristics. Therefore the distribution of the flathead catfish was also indirectly influenced by those factors which influence the distribution of freshwater drum and gizzard shad. On the other hand, LUX and SMITH (1960) have shown that in one small Minnesota lake, angler success for northern pike *(Esox ludous),* bluegill *(Lepomis macrochirus)* and crappie *(Promoxis nigromaculates),* was inversely related to food availability .of forage fish and benthic invertebrates, but that physical and chemical factors exerted little or no measurable influence upon angler success except as they influenced food production. In Lake Victoria, records of gillnet fish catches, mainly from inshore areas, indicate lowest catches during July-August, the only period of complete isothermy when ideal dissolved oxygen conditions obtain throughout the entire depth and breadth of the lake (FISH 1957; TALLING 1957 and 1966; KITAKA (personal observations». Recent bottom trawling experiments throughout the lake have confirmed that the majority of the fish species are demersal. It now appears that the drop in gillnet catches during July-August may be the result of dispersal migrations into deep waters of fish populations previously limited to the shallower well oxygenated waters by the anoxic conditions which prevail in the bottom waters before the breakdown of thermal stratification. This does not rule out the importance of other factors. Studies of currents in lakes of the western coast of North America have shown predictable patterns of movement of salmon fry through these lakes. Vertical distribution of certain fishes has been related to chemoclines, thermoclines, density currents and light intensity (FREY 1937; DENDY 1948; BORGES 1950). In those species which have been shown to be adversely affected by the results of extreme physical-chemical stratification, increasing eutrophication has predictedly resulted in their disappearance as, for example, cisco in some lakes in North America (FREY 1937).

Limnological information has been useful in arriving at management decisions regarding introduction of new fish species in several inland waters: studies and comparisons of the physical, chemical and biological conditions of Redberry Lake, a highly saline lake, and Waskesiu Lake, a typical whitefish lake, were important in deciding to introduce whitefish *(Coregonus clupeaformis)* and pikeperch *(Stizostedion vitreum)* into Redberry Lake (RAWSON 1946). According to DR. F. HENDERSON (personal communication) studies of temperature and food availability in the north delta lakes in Egypt were important in deciding to introduce mullet fry and glass eel into the lakes, and studies of the benthic fauna of the saline Lake Qarun were important to the decision to introduce the marine fish *(Solea vulgaris)* into this lake where it now forms 30% of the total annual catch. The effect of salinity on the breeding of mullet species determines which species will successfully acclimatize and breed in brackish lakes so that salinity studies by EL-ZARKA (personal communication from DR. F. HENDERSON) led to selecting *Mugil sailnes* for Lake Qarun. McCARRAHER and GREGORY (1970) have found that whereas the euryhaline Sacramento perch)*(Archoplites interruptus)* will successfully acclimatize and breed in chloride-sulphate waters with salinities near 17,000 mg/I, it will not do so in sodium-potassium carbonate waters exceeding 800 mg/l in total alkalinity. A good knowledge of the relative amounts of the salts of the waters of the North American lakes has, therefore, been invaluable in selecting the lakes where this species will survive.

Limno10gical factors have also been shown to influence feeding, growth rates and survival of certain fishes especially during their early stages: in Lewis and Clark Lake, South Dakota, RUELLE (1971) has found significant positive correlation between rates of growth of age 0 white bass *(Morone chrysops)* and water temperature, although the availability of food, especially of forage fish, was another factor which proved even more important in later juvenile stages. In Lake Erie, LANGLOIS (1948) demonstrated that turbidity and plankton abundance control the size of surviving year classes of important commercial fishes, and that the crop of fish available for capture in any given year was not related to fishing intensity in past seasons, but instead to the amount of silt carried into the lake during some preceding year when the fish were hatching. Similarly, in Lakes Oahe and Sharpe, HASSLER (1970) found that large year classes of northern pike were associated with stable to rising water level and temperature, flooded vegetation, and calm weather during spawning seasons, whereas small year classes with abrupt water temperature fluctuations, dropping water level and high silt deposits. Sudden drops in temperature below 10° C or prolonged temperatures near 5° C, and silt deposition of 1.0 mm per day caused mortalities of 100% and 97% respectively during early embryonic development, though after hatching available food was the more important factor in survival. HAVEY and DAVIS (1970) have found that stream flow in the dry season, as indicated by rainfall, was the most important factor influencing survival from age 0+ of landlocked salmon *(Salmon salar)* in spawning and nursery grounds at Barrow stream, Maine notwithstanding the presence of other variables such as standing crops of other fishes, and water temperature. The influence of stream flow was such that survival could be reliably predicted from rainfall. Such information is of tremendous importance from the point of view of fishery management. While the adverse effects of silt in Lake Erie might be changed by intensive soil conservation practices on the land in the watersheds tributary to it, these and most of the other factors referred to above could be changed by water control practices using storage dams to regulate stream flow in dry months, silt deposition in spawning and nursery areas and water level fluctuations' (BRIGGS 1948).

The importance of limnology in fishery management has long been recognized, witness the long list of studies which have attempted to relate certain limnological factors to lake productivity, and even to estimate potential fish production from such limnological indices (RAWSON 1930, 1942, 1947, 1951, 1952, 1953a, 1953b, 1955, 1958, 1960; RAWSON and ATTON 1953; ROELOFS 1944; MOYLE 1946; REIMERS *et al.* 1955; NORTHCOTE and LARKIN 1956; HAYES 1957; RYDER 1965). Briefly, the factors which have emerged as the most important in determining lake productivity are:

(1) Lake morphometry, which has been found to be best represented by the mean depth of the lake (RAWSON 1952). In general, it has been found that other things being equal, beyond a certain mean depth, deeper lakes are not as productive as shallow ones.
(2) Geology and dissolved nutrients, which together are referred to as the edaphic factor, and have been found to be well taken care of by the total dissolved solids. The higher the value of total dissolved solids, the more productive the lake should be.
(3) The climatic factors, which include length of the growing season and temperature, especially of the epilimnion, during this period, etc.

While it is difficult to say which of the three factors is the most important, it has been found that in a comparison of the productivity of a group of lakes belonging to a single climatic region, the effects of the climatic factors are greatly overshadowed by those of the morphometric and edaphic factors. Similarly, RAWSON (1952, 1955) has shown that morphometry expressed by mean depth is the dominant factor influencing biological production in many large lakes across Canada, whereas for the British Columbia lakes, NORTHCOTE and LARKIN (1956) found the total dissolved solid content of the water to be the most important factor. They found a significant increase in quantities of plankton and fish with increase in total dissolved solid content of the waters, and a similar relationship for the bottom fauna. They also found that quantities of fauna including fish from lakes of great mean depth were never as high as those found in lakes of low mean depth; but in one particular region, neither total dissolved solids nor mean depth could be used either singly or together to predict quantities of plankton, bottom fauna or fish. Recently, RYDER (1965) has demonstrated a significant positive correlation between fish yield and morphoedaphic index (total dissolved solids divided by mean depth) for 34 north-temperate lakes, and conclude that if the total dissolved solids and the mean depth of a lake are known, its morphoedaphic index can be calculated and its potential fish production estimated from a graph relating the fish production and morphoedaphic index for a group of lakes within the same climatic region. The accuracy of such an estimate would depend on the accuracy of the estimates of the fish yields of the lakes used in plotting the graph, since their morphoedaphic indices could be determined much more accurately.

Recently HRBACEK (1969) has found significant positive correlation between Kjeldahl nitrogen in unit volume of water and the mean Kjeldahl nitrogen in zooplankton, and fish yield.

Studies on streams of western Europe by HUET (1959) have indicated that these streams may be divided into four usually quite distinct biological zones, each with a characteristic fish fauna with a diagnostic fish. The biological zones of the stream are related to the physical nature of the water course, especially its cross and longitudinal sections and gradient. From longitudinal profiles of these rivers and from graphs relating stream gradient, stream breadth and fish faunal zones (slope-graph), Huet has concluded that, "In given biogeographical areas, rivers or stretches of rivers of like breadth, depth and slope, have nearly identical biological characteristics and very similar fish populations". Therefore, "... physical data describing the longitudinal profile of a stream, when used with data for average width of the stream itself, can be used to determine the fish zone of any section of the stream", and if such information is available for any stream, "... surveys and inventories used as a basis for fish management can be greatly facilitated. The slope-graph principle is also useful in solving problems related to stocking of native or exotic fishes. Locations suitable ecologically for the species to be stocked can be better and more easily identified. It might be noted, along this line, that acclimatization of the small mouth bass *(Micropterus dolomieu)* has been successful in the Semois River of Belgium where the slope is comparable to American rivers in which this species does well".

Recognition of the chemical nutrients limiting biological production in certain lakes has been the basis of enlightened recommendations and management decisions for artificial fertilization of such lakes and in some cases, their fish food and fish production has increased (BALL 1948; McINTYRE and BOND 1962; YASHOUV 1963). But in order to result in prolonged increase in fish production, such recommendations must also be based on some background knowledge of seasonal variations in stratification structure, oxygen concentration and the ways in which the lake soils may influence the economy of fertilization in a purely mechanical sense. In a permanently stratified lake, for example, the additional nutrients would end up permanently locked up in the hypolimnion so that their effect would be only temporary. In temperate regions, mass winter kills of fish in fertilized previously unproductive lakes have been associated with oxygen depletion in the water under the ice, resulting from eutrophication of these lakes due to fertilization (BALL 1948, TANNER 1960).

Recent studies of the effects of artificially induced circulation of lakes and reservoirs (SCHMITZ and HASLER 1958; IRWIN, SYMONS and ROBECK 1957) are potentially important both as a management technique, and in interpreting the potential effects of a given stratification regime on fish production.

In conclusion then it can be said that limnological information is of tremendous importance in solving some of the problems related to the development and management of inland fisheries. It is to be hoped that these comments and the references cited in this paper, will be of benefit in directing future research programmes with a view to making use of any limnological shortcuts to answer some of the management problems that confront us in our developing countries. In this regard, the importance of simultaneous collection of fishery and limnological data in our future programme must be emphasized. Where this is not possible, limnologist and even fishery biologists should always endeavour to include in their measurements those limnological variables which have been shown to have some predictive value in fish management.

SUMMARY

Limnology is the study of all events physical, chemical or biological occurring in freshwater bodies. Fishery management may be regarded as the art and science of producing the highest sustainable yield of wild fish of the best quality in the most economic way. Limnological information is basic to the decisions required for such management. The distribution of food organisms may condition the distribution of fishes feeding on them. Decisions regarding introductions of exotic species can be arrived at by the study of the physical and chemical conditions of the donor and recipient water bodies. Limnological factors have also been shown to influence feeding, growth and survival of many fish species. Predictions of production potentials can be arrived at by consideration of lake morphology, geology and chemistry. Stream morphology may sImilarly be used to predict the biological characteristics of water courses. Recognition of chemical nutri-

ents limiting biological production can serve to guide artificial fertilization.

RESUME

La limnologie est I'etude de tous les phénomenes physiques, chimiques ou biologiques se produisant dans les plans d'eau douce. L'amenagement des pêche peut être considéré comme l'art et la science de produire des captures maximalesequilibrees de poisson de la meilleure qualite, de la façon la plus economique. Les donnees limnologiques sont à la base des decisions requises pour un tel amenagement. La distribution des organismes alimentaires peut conditionner la distribution des poissons que s'en nour-' rissent. Les décisions concernant I'introduction des especes exotiques peuvent être atteintes par l'etude des conditions physiques et chimiques des plans d'eau d'origine et destinataires. II a été démontré que les facteurs limnologiques influent egalement *sur* l'alimentation, la croissance et la survie de plusieurs especes de poisson. Les previsions des potentiels de production peuvent être faites en tenant compte de la morphologie et de la chimie des lacs. La morphologie des cours d'eau peut être egalement employee pour prevoir leurs characteristiques biologiques. La connaissance des nutrients chimiques limitant la production biologique peut servir de guide à la fertilisation artificielle.

REFERENCES

Ball, R. C. (1948). Fertilization of natural lakes in Michigan. *Trans. Amer. Fish. Soc.,* 78: 145-55.

Bennet, G. W. (1962). Management of Artificial Lakes and Ponds. Reinhold Publishing Corporation, New York.

Borges, H. M. (1950). Fish distribution studies, Niangua *Arm* of the Lake of the Ozarks, Missouri. *J. Wildlife Mgt.,* 14: 16-33.

Briggs, J. C. (1948). The quantitative effects of a dam upon the bottom fauna of a small California stream. *Trans. Amer. Fish. Soc.,* 78: 70-81.

Dendy, J. S. (1948). Predict'ing depth distribution of fish in three T.V.A. storage-type reservoirs. *Trans. Amer. Fish. Soc.,* 75: 65-71.

Fish, G. R. (1957). A seiche movement and its effects on the hydrology of Lake Victoria. *Publ. Colonial Office, Lond.,* 10: 68 p.

Frey, F. E. J. (1937). The summer' migration of cisco, *Leucichthys artedi* (Lesuer), in Lake Nipissing, Ontario. *Uni. Toronto Stud. Bioi. Ser.* 44 *(Publ.) Om. Fish. Res. Lab.,* 55: 91.

Hassler, T. J. (1970). Environmental influence on early development and year-class strength of northern pike in Lakes Oahe and Sharpe, South Dakota. *Trans. Amer. Fish. Soc.,* 99: 369-75.

Havey, K. A., and R. M. Davis (1970). Factors influencing standing crops and survival of juvenile salmon at Barrows Stream, Maine. *Trans. Amer, Fish. Soc.,* 99: 297-311.

Hayes, F. R. (1957). On the variation in bottom fauna and fish yield in relation to trophic level and lake dimensions. *J. Fish. Res. Bd. Canada,* 14: 1-32.

Hrbacek, J. (1969). Relations of biological productivity to fish production and to the maintenance of water quality, p. 176-85. *In* L. E. Obeng (ed.), *Man-made Lakes,* Ghana Univ. Press, Accra.

Huet, M. (1959). Profiles and biology of Western European Streams as related to fish management. *Trans. Amer. Fish. Soc.,* 88: 155-63.

Hutchinson, G. E. (1957). A treatise on limnology, Vol. 1. Geology, physics and chemistry. Wiley, New York.

——(1967). A treatise on limnology, Vol. 2. Introduction to lake biology and the Iimnoplankton. Wiley, New York.

Irwin, H. W., J. M. Symons, and G. G. Robeck (1%7). Water quality in impoundments and modifications from destratification. Reservoir Fishery Sympos,ium, edited, Reservoir Committee, Southern Division, *A.F.S.*

Kilham, P. (1971). A hypothesis concerning silica and the freshwater plankton diatoms. *Limnology. Oceanorgr.*, 16: 10-18.

Kitaka, G. E. B. Personal observations.

Klaassen, H. E., and R. Marzolf (1971). Relationships between distribution of benthic insects and bottom-feeding fishes in Tuttle Creek Reservoir, p. 385-96. *In* C. E. Hall (ed.), Reservoir Fisheries and Limnology, Publ. No.8, AF.S.

Langlois, T. H. (1948). Cited in Bennet, G. W. (1962). Management of artificial lakes and ponds. Reinhold Publishing COf1poration, New York.

Lund, J. W. G. (1958). Primary production in inland waters. The Biological Production of Britain, Published by the Institute of Biology, London.

--(1965). Ecology of the freshwater phytoplankton. *Bioi. Rev. Camb"idge Phil. Soc.*, 40: 231-93.

Lux, F. E., and L. L. Smith, Jm. (1960). Some factors influencing seasonal 'changes ,in angler catch in a Minnesota lake. *Trans. Amer. Fish. Soc.*, 89: 67-79.

McCarraher, D. B., and R. W. Gregory (1970). Adaptability and current status of introductions of Sacramento 'perch, *Archoplites interruptus*, in North America. *Trans. Amer. Fish. Soc.*, 99: 700-7.

McIntire, C. D., and Bond (1962). Effects of artificial fertilization on plankton and benthos abundance in four experimental ponds. *Trans. Amer. Fish. Soc.*, 91: 303-12.

Midgley, S. H. (1968). A study of Nile perch in Africa and consideration as to its suitability for Australian tropical inland water. The Winston Churchill Memorial Trust. Fellowship Report No.3, Canberra City.

Moyle, J. B. (1946). Some indices of lake productivity. *Trans. Amer. Fish. Soc.*, 76: 322-34.

Northcote, T. G., and P. A. Larkin (1956). Indices of productivity in British Columbia lakes. J. *Fish. Res. Bd., Canada,* 13 515-40.

Norton, J. L. (1968). Cited in Summerlelt, R. C. (1971). Factors influencing the horizontal distribution of several fishes in an Oklahoma reservoir, p. 425-30. *In* G. E. Hall (00.), Reservoir fisheries and limnology, Publ. No.8, AF.S.

Pearlsall, W. H. (1921). The development of vegetation in the English lakes, considered in relation to the general evolution of glacial lakes in rock basins. *Proc. Roy. Soc., Ser. B.*, 92: 248-59.

Rawson, D. S. (1930). The bottom fauna of Lake Simcoe and its role in the ecology of the Lake No. 34. Publications of the Ontario F.isheries Research Lab. No. 40, Toronto University Press.

——(1942). A comparison of some large Alpine lakes in Western Canada. *Ecol.* 23: 143-61.

——(1946). Successful introduction of fish in a large saline lake. Reprinted from the *Canadian Fish Culturist,* Ottawa.

——(1947). Estimating the fish production of Great Slave Lake. *Trans. Amer. Fish. Soc.*, 77: 81-91.

——(1951). The total mineral content of lake waters. *Ecal.*, 32: 669-72.

——(1952). Mean depth and the fish production of large lakes. *Ecol.*, 33: 513-21.

Rawson, D. S. (1953a). The bottom fauna of Great Slave Lake. J. *Fish. Res. Bd., Canada,* 10: 486-519.

--(1953b). The standing crop of net plankton in lakes. J. *Fish. Res. Bd., Canada.* 10: 224-37.

--(1955). Morphometry as a dominant factor in the productivity of large lakes. *Proc. Intern. Ass. Theoretical Appl. Limnol.*, 12: 164-75.

--(1958). Indices of lake productivity and their significance in predicting conditions in reservoirs and lakes with disturbed water levels, p. 1-111. *In* P. A Larkin (ed.), The investigation of ,fish-power problems. H. R. MacMillan lectures in fisheries.

——(1960). A limnological comparison of twelve large lakes in Northern Saskatchewan. *Limnol. Oceanogr.*, 5: 195-211.

Rawson, D. S. and F. M. Atton (1953). Biological investigation and fisheries management at Lac La Ronge, Saskatchewan. Special publication by the Department of Natural Resources Fisheries Branch, 1953.

Reimers, N., J. A. Maciolek, and E. P. Pister (1955). Limnological study of the lakes in Convict Creek Basin Mono County, California. *Fish. Bull. Fish and Wildlife Service,* 56: 437-503.

Roelofs, E. W. (1944). Water soils in relation to lake production. Technical Bulletin 190, Michigan State College.

Ruelle, R. (1971). Factors influencing growth of white bass in Lewis and Clark Lake, p. 411-23. *In* G. E. Hall (ed.), Reservoir fisheries and limnology, Publ. No.8, AF.S.

Ryder, R. A (1965). A method for estimating the potential fish production of north-temperate lakes. *Trans. Amer. Fish. Soc.*, 94: 214-8.

Schmitz, W. R. and A D. Hasler (1958). Artificially induced circulation of lakes !by means of compressed air. *Science,* 128: 1088-9.

Summerfelt, R. C. (1971). Factors influencing the horizontal distribution of several fishes in an Oklahoma reservoir, p. 425-39. *In* G. E. Hall (ed.), Reservoir fisheries and limnology, Pub!. No.8, AF.S.

Talling, J. F. (1957). Some observations on the stratification of Lake Victoria. *Limnol. Oceanogr.,* 11: 213-21.

--(1%6). The annual cycle of stratification and phytoplankton growth in Lake Victoria (East Africa). *Int. Revue. Ges. Hydrobiol.,* 51: 545-621.

Tanner, H. A (1960). Some consequences of adding fertilizer to five Michigan trout lakes. *Trans. Amer. Fish. Soc.,* 89: 189-205.

van Landingham, S. L. (1964). Some physical and generic aspects of fluctuations in non-marine plankton diatom populations. *Bot. Rev.,* 30: 437-78.

Yashouv, A (1%3). Increasing fish production in ponds. *Trans. Amer. P'ish. Soc.,* 92: 292-7.

SPECIAL ISSUE II

The African Journal of Tropical Hydrobiology and Fisheries

CONTENTS *Page*

EAST AFRICAN LITERATURE BUREAU